

SUSPENDED SUBSTRATE LOW LOSS COUPLER

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates in general to a suspended substrate quadrature coupler for combining two receive or transmit amplifiers for increased power output, reduced port VSWR and improved reliability.

2. Description of the Background Art

[0002] There is a need for low cost, low insertion loss, high-power handling capability quadrature couplers that can be inserted into an integrated circuit module assembly (IMA). For receiver modules, insertion loss is critical to minimize the noise figure contribution between the antenna and the first low noise amplifier. Any coupler insertion loss will directly add to the overall noise figure of the receiver module. For transmitter modules, low-loss and high power handling is critical if the coupler follows the power amplifier. For transmit applications, the coupler may need to handle over one hundred watts of RF output signal from two power amplifiers. The coupler needs to be low loss so that maximum power is transferred from the power amplifier to the transmit antenna and to minimize the wasted transmit power heating the coupler.

[0003] Prior art microwave couplers include microstrip Lange couplers, waveguide couplers and stripline couplers. Low insertion loss Lange couplers require precision lithography to maintain close spacing between coupler fingers. These tight spacing requirements are difficult to achieve in low cost printed circuit processes. In addition, Lange couplers require thick substrates for low loss and to increase the line-to-line spacing needed for a 3 dB quadrature coupler. Lange couplers are also not suited

for low cost printed circuit implementation because of the need for crossovers to interconnect the alternate fingers. Waveguide couplers can handle high power RF signals with low loss but are very large at cell phone frequencies and are not suitable for integration with active devices.

[0004] Stripline couplers are the most common approach for quadrature 3 dB couplers at cell phone frequencies because of the well matched even and odd mode coupled transmission line impedance. These couplers require multilayer printed circuit fabrication techniques. The dielectric loss of the circuit board material is critical for low loss stripline couplers because all of the electric field energy is stored in the dielectric material. Suspended stripline couplers can be fabricated as a single layer printed circuit board but normally have the disadvantage of very different even and odd mode velocity in coupled transmission line structures. The electric field energy is stored mostly in air for the even mode while there is more electric field energy stored in the dielectric material for the odd mode, thus slowing the odd mode velocity relative to the even mode. The difference in coupled line phase velocity causes generally poor performance for simple suspended stripline couplers. Thus, there is a need for an improved suspended stripline coupler that provides closer mode velocity matching and improved coupler performance.

SUMMARY OF THE INVENTION

[0005] The present invention addresses the foregoing need through provision of a low loss suspended substrate coupler which includes a dielectric substrate, a first conductor metallization forming a first transmission line on a topside of the substrate and a second conductor metallization forming a second transmission line on the bottom

side of the substrate. To provide closer mode velocity matching, a key feature of the coupler is the provision of capacitive loading or coupling to ground at discrete intervals between the transmission line on the topside of the substrate and the transmission line on the bottom side of the substrate. This capacitive loading is formed by incorporating capacitance stubs in each transmission line section at pre-selected intervals, each of which is opposite a corresponding one of a plurality of grounded stubs on the other side of the substrate. This capacitive loading to ground at discrete intervals along the transmission line represents a low cost method for providing closer even to odd mode velocity matching across a given frequency bandwidth, corresponding to improved isolation and lower VSWR.

[0006] Preferably, to improve performance, the coupler design also uses substrate vias to provide microstrip interfaces and microstrip matching elements on one side of the substrate for the coupler ports at both ends of each coupled transmission line. In addition, the substrate coupler is preferably mounted in an enclosure with controlled spacing to ground above and below the substrate to control the transmission line impedance of the coupled lines and to provide shielding of the coupler.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The features and advantages of the present invention will become apparent from the following detailed description of a preferred embodiment thereof, taken in conjunction with the accompanying drawings, in which:

[0008] FIG. 1 is a perspective illustration of a suspended substrate coupler that is constructed in accordance with the preferred embodiment of the present invention;

[0009] FIG. 2 is front view of the coupler of FIG.1 shown in cross section;

[0010] FIG. 3A is a top view of the suspended substrate employed in the coupler of FIG. 1 and showing the transmission line configuration formed thereon; and

[0011] FIG. 3B is a bottom view of the suspended substrate, also showing the transmission line configuration formed thereon.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0012] FIG. 1 illustrates a suspended substrate quadrature coupler 10 that is constructed in accordance with the preferred embodiment of the invention. The coupler 10 includes a housing 12, which is preferably made from metal, metal coated plastic or any other suitable electrically conductive material and includes a removable cover 13. Disposed in the housing 12 is a dielectric substrate 14.

[0013] As illustrated in FIG. 2, the substrate 14 is mounted on a ledge 15 of the housing 12 in a suspended manner such that a first cavity 16 is formed between a topside 17 of the substrate 14 and the cover 13, while a second cavity 18 is formed between a bottom side 19 of the substrate 14 and a floor 20 of the housing 12. A transmission line coupler circuit 21 is formed on both the top and bottom sides of the substrate 14 as will be discussed in detail in conjunction with FIGs. 3A and 3B. The mounting of the substrate 14 in the housing 12 with controlled spacing to ground above and below the substrate 14 controls the transmission line impedance of the coupler circuit 21. In addition, the housing 12 provides shielding of the coupler circuit 21.

[0014] As is conventional in a quadrature coupler, a plurality of connectors 22 is attached to the housing 12 for facilitating connection of various electrical components to a group of 4 ports including an input port 23, a direct output port 24, an isolation port 26

and a coupled output port 28. The various components of the coupler 10 are secured together using any suitable fastening means such as a plurality of bolts 30.

[0015] FIGs. 3A and 3B illustrate the details of the transmission line coupler circuit 21 that is formed on the top and bottom sides 17 and 19 of the suspended substrate 14. In FIG. 3A, a top view of the substrate 14 is shown in which the transmission line coupler circuit 21 comprises a plurality of various shaped conductor lines or metallizations disposed on the topside 17 of the substrate 14. The largest of these is a transmission line metallization which includes a first microstrip interface 32 for connecting the input port 23 to a first end of a transmission line 34 and a second microstrip interface 36 for connecting a second end of the transmission line 34 to the direct output port 24. Adjacent each of the microstrip interfaces 32 and 36 is a matching stub 38 and 40, respectively. Four capacitive stubs 42 are spaced at predetermined intervals along the transmission line 34. As illustrated, the stubs 42 extend in alternating directions first from one side 44 of the transmission line 34 and then from an opposite side 46 of the transmission line 34.

[0016] First and second microstrip interfaces 48 and 50 are provided for interfacing a bottom transmission line (to be discussed later in conjunction with FIG. 3B) of the coupler 10 at a first end to the isolation port 26 and at a second end to the coupled output port 28, respectively. Each of the interfaces 48 and 50 includes a corresponding one of third and fourth matching stubs 52 and 54, as well as a corresponding one of first and second terminals 56 and 58. The terminals 56 and 58 connect the interfaces 48 and 50, respectively, to one or more conductive pass-throughs or vias in the substrate 14 that connect to the transmission line coupler circuit

21 on the bottom side 19 of the substrate 14 as illustrated in and discussed in conjunction with FIG. 3B.

[0017] First and second ground metallizations 60 and 62 are also disposed on the topside 17 of the substrate 14, each of which is grounded along their outer edges either to a plurality of substrate vias 63 or directly to the housing 12 when assembled thereto. A first pair of ground stubs 64 is provided in the first ground metallization 60, while a second pair of ground stubs 66 is provided in the second ground metallization 62. As illustrated, each of the ground stubs 64 and 66 extends almost into contact with the transmission line 34 and is positioned directly across the transmission line 34 from a corresponding one of the capacitance stubs 42. Third and fourth ground metallizations 68 and 70 are also disposed along opposite ends of the substrate 14, which provide a ground reference adjacent each of the various matching stubs 38, 40, 52 and 54.

[0018] With reference to FIG. 3B, the transmission line coupler circuit 21 on the bottom side 19 of the substrate 14 comprises a second transmission line 72, which includes first and second terminals 74 and 76 that connect to the same pass-through connections or vias to which the terminals 56 and 58, respectively, on the topside 17 of the substrate 14 are connected. Four capacitive stubs 78 are spaced at predetermined intervals along the transmission line 72. As illustrated, the stubs 78 extend in alternating directions first from one side 80 of the transmission line 72 and then from an opposite side 82 of the transmission line 72.

[0019] First and second ground metallizations 84 and 86 are also disposed on the bottom side 19 of the substrate 14, each of which is grounded to a plurality of substrate vias 88 or to the housing 12 when assembled thereto. A first pair of ground

stubs 90 is provided in the first ground metallization 84, while a second pair of ground stubs 92 is provided in the second ground metallization 86. As illustrated, each of the ground stubs 90 and 92 extends almost into contact with the transmission line 72 and is positioned directly across the transmission line 72 from a corresponding one of the capacitance stubs 78.

[0020] With the foregoing arrangement, broadside transmission line coupling is provided between the first transmission line 34 on the topside 17 of the substrate 14 and the second transmission line 72 on the bottom side 19 of the substrate 14. Additional capacitive coupling is provided to ground for the two transmission lines 34 and 72. In particular, the capacitance stubs 42 disposed along the first transmission line 34 are each coupled to ground by the corresponding ground stubs 90 and 92 on the bottom side 19 of the substrate 14 that are aligned beneath the capacitance stubs 42. Similarly, the capacitance stubs 78 disposed along the second transmission line 72 are each coupled to ground by the corresponding ground stubs 64 and 66 on the top side 17 of the substrate 14 that are aligned above the capacitance stubs 78. In this manner, each capacitance stub/ground stub pair thus forms a coupling capacitor between ground and either of the two transmission lines 34 or 72. This capacitive loading to ground at discrete intervals along the transmission lines provides closer even to odd mode velocity matching across a given frequency bandwidth, corresponding to improved isolation and lower VSWR.

[0021] Performance of the coupler 10 is further enhanced through provision of the elements at both ends of each coupled line 34 and 72, which are the microstrip interfaces 32, 36, 48 and 50 and microstrip matching elements 38, 40, 52 and 54 for

each of the four coupler ports 23, 24, 26 and 28, respectively. The coupler 10 thus provides a very low cost method to equalize the even and the odd mode velocity of a suspended substrate coupler and when employed in receivers or transmitters, provides lower noise figure LNA receiver front ends and lower loss power transmitter sources.

[0022] Although the invention has been disclosed in terms of a preferred embodiment, it will be understood that numerous variations and modifications could be made thereto without departing from the scope of the invention as set forth in the attached claims. For example, although the preferred embodiment of the subject coupler is a four-port quadrature coupler, the invention could be employed with any type of suspended substrate coupler having transmission line sections that can be capacitively coupled to improve performance.